Tropical cyclone products and product development at CIRA/RAMMB

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RAMMB Regional and Mesoscale Meteorology Branch
NOAA Satellites and Information
National Environmental Satellite, Data, and Information Service
CIRA Cooperative Institute for Research in the Atmosphere

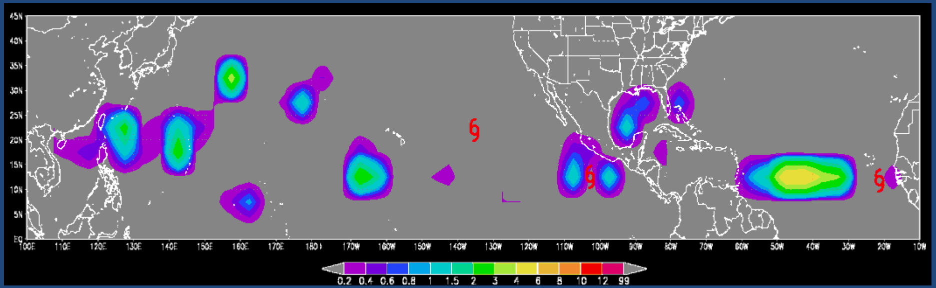
Outline

- Tropical Cyclone Genesis Product
- Multi-platform Tropical Cyclone – Surface Wind Analysis
- Monte Carlo Tropical Cyclone Wind Probability Product
- Intensity Forecasting Using the Logistic Growth Equation

Tropical Cyclone Formation Probability Product

<u>Product Description</u>

Estimates the 24-hr probability of TC formation within each 5x5 grid box in domain



Uses both environmental (GFS analyses and ATCF TC positions) and convective (geostationary satellite water vapor imagery) predictors

Displays real-time and climatological contour plots of TC formation probability (top right) and predictor values, as well as cumulative/average sub-basin values

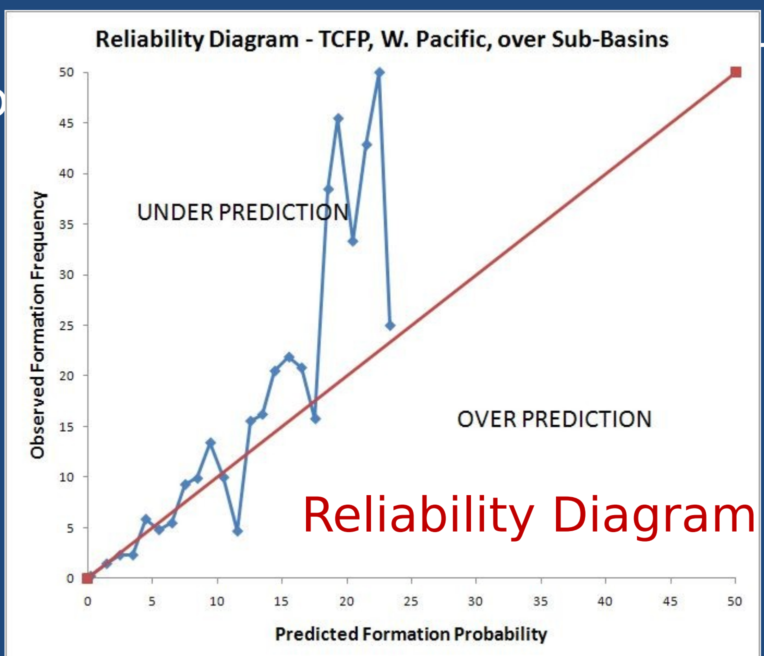
<u>Current Predictors</u>

- Climatology
- Latitude
- Distance to existing TC
- Levitus SST
- Land coverage
- 850-hPa Circulation
- 850-200 hPa Vertical Shear
- Vertical Instability
- 850-hPa Horiz. Divergence
- Cold Cloud Coverage
- Average Brightness Temp

Tropical Cyclone Formation Probability Product (Cont…)

<u>2008 Verification – W. Pacific</u>

ROC Skill Score (Y vs. N) = 0.26 → Skillful
Brier Skill Score (RMSE) = 0.029 → Skillful



<u>Upcoming Improvements</u>

- New/Experimental Predictors
  - Reynold’s SST to replace Levitus
  - Variance of IR radiance (Ritchie et al. 2009, IHC)
- Expanded Domain
  - Global product currently under development
- Increase probability estimate from 24 hr to 48+ hrs

Multi-platform Tropical Cyclone -Surface Wind Analysis (MTC-SWA)

Product Description

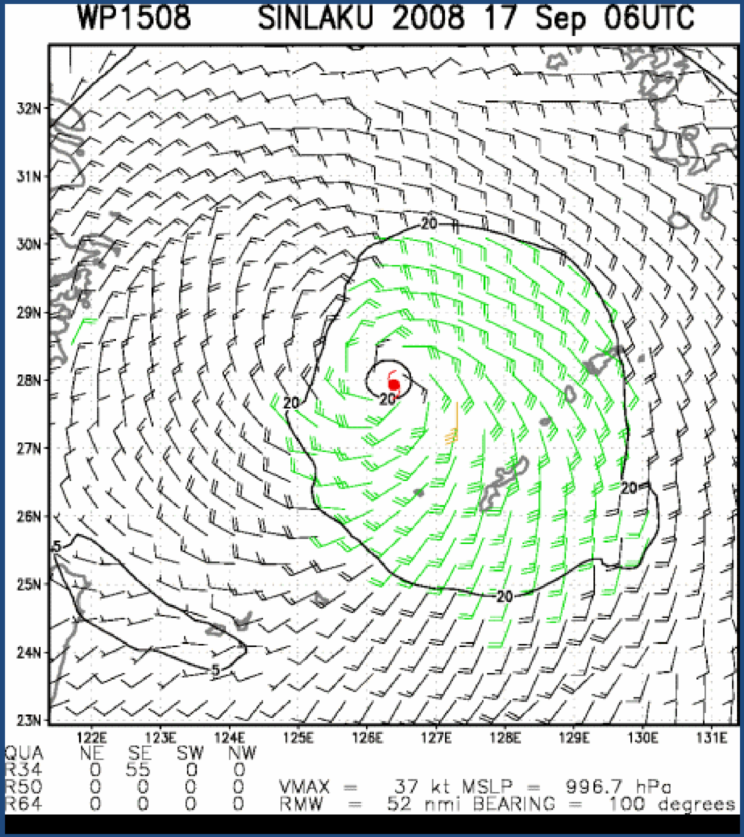
Global Product

- 6-hourly provided to JTWC via ATCF
- Produced at CIRA
- Being transitioned to NESDIS

Input Data

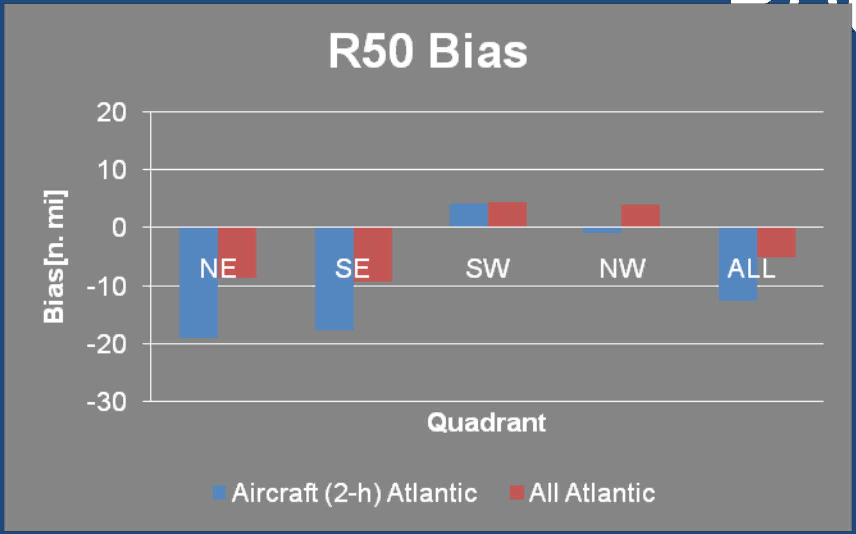
- Scatterometry
  - A-Scat
  - QuikSCAT
- Cloud/Feature Drift Winds
  - JMA via NRL & NESDIS
- AMSU 2-D Winds (Bessho et al. 2006)
  - NCEP
- IR Flight-Level Proxy Winds (Mueller et al. 2006)

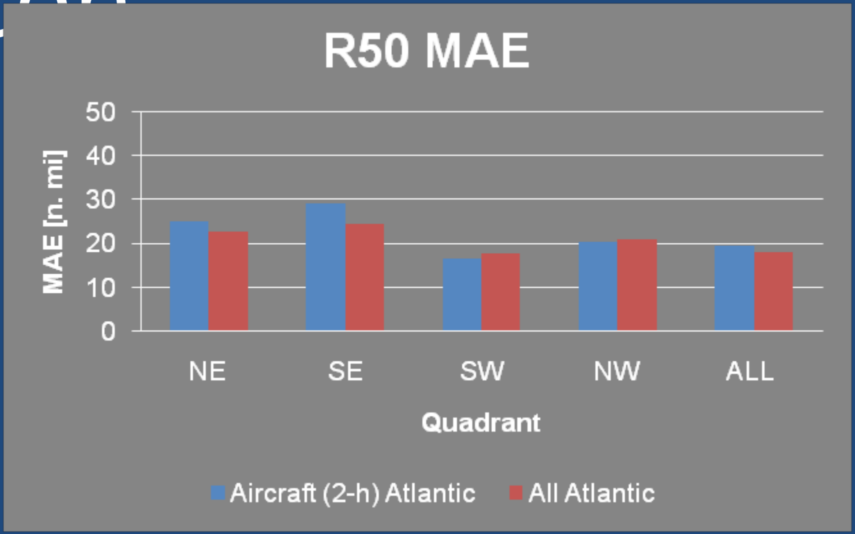
Six-hourly Analyses (48-h loop)

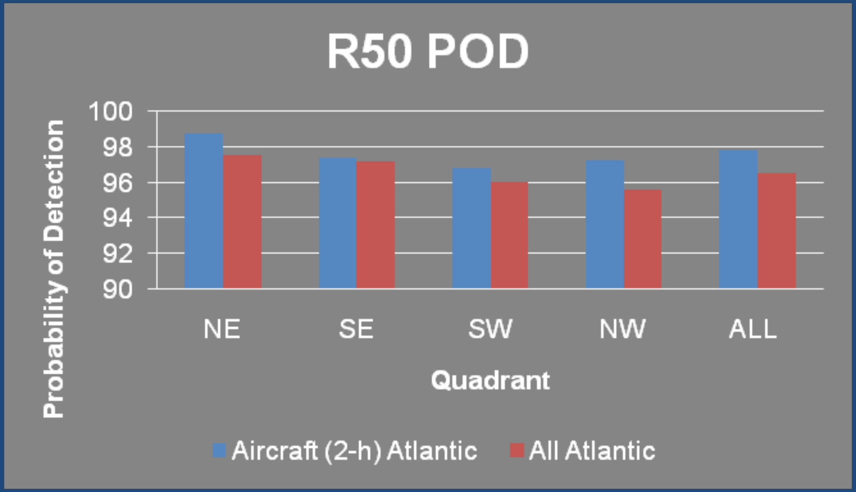


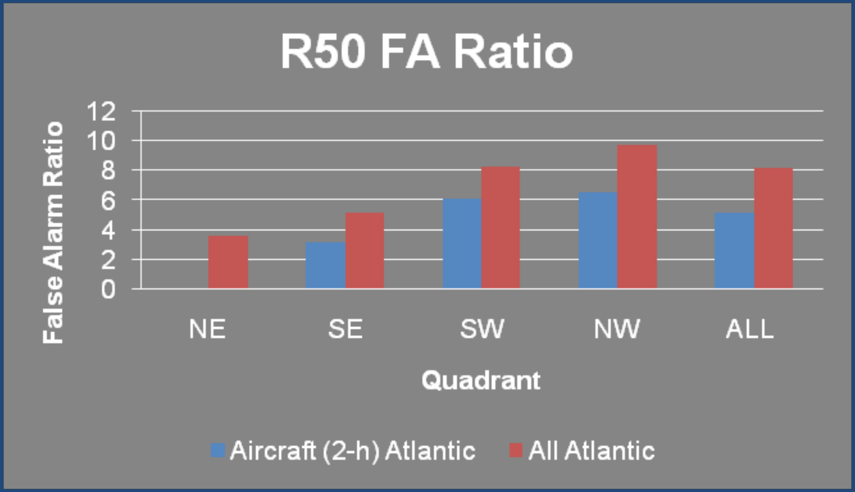
st/real-time cases available at http://rammb.cira.colostate.edu/products/tc_realt

2008 Atlantic Verification with Recon







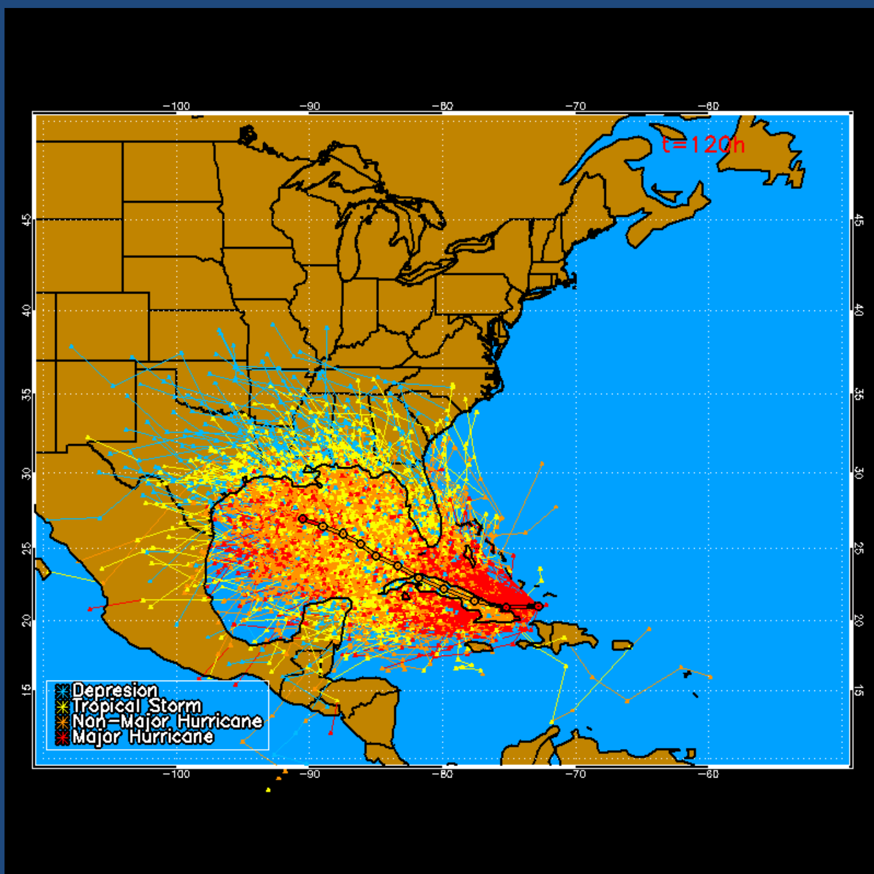


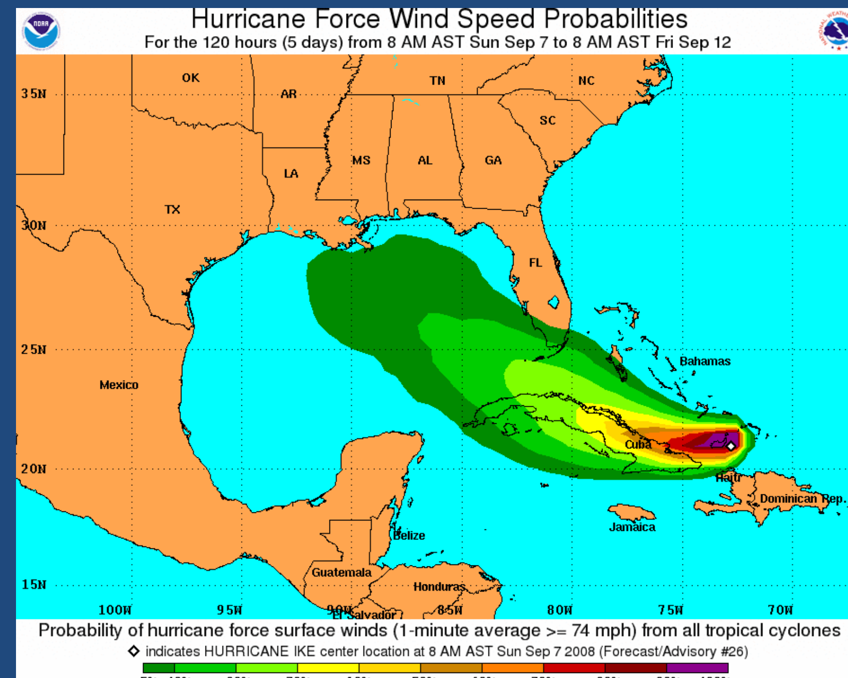
Full verification (RMSE, POD, R34, R64 etc.) available from John.Knaff@noaa.gov

Monte Carlo Wind Probability Model

- Estimates probability of 34, 50 and 64 kt wind to 5 days
- Implemented at NHC/JTWC for 2006 hurricane season
  - Replaced Hurricane Strike Probabilities
- 1000 track realizations from random sampling NHC *track error* distributions
- Intensity of realizations from random sampling NHC *intensity error* distributions
  - Special treatment near land
- Wind radii of realizations from radii CLIPER model and its *radii error* distributions
- Serial correlation of errors included
- Probability at a point from counting number of realizations passing within the wind radii of interest

MC Probability Example
Hurricane Ike 7 Sept 2008 12 UTC





64 kt 0-120 h Cumulative Probabi

Monte Carlo Wind Probability Application: Objective Warning/TC-COR Guidance

- Goal: Develop an objective hurricane warning scheme based on wind probabilities (Atlantic)
- Approach:
  - 2004-2008 land-threatening Atlantic TCs as development sample
  - Examined 64-kt, 36-h cumulative MC wind probabilities versus NHC hurricane warnings over sample
  - Choose probability thresholds
    - P_{up} = when hurricane warnings issued
    - P_{down} = when hurricane warnings dropped
    - Thresholds chosen by maximizing the fit (by R^2, MAE, averages) of the total distance warned and the total duration of warnings per storm between the scheme and NHC official warnings
    - Imposed condition that scheme <u>could not miss any official warnings</u>

Experimental TC-COR Guidance

- For Atlantic, p_{up} = 8.0%, p_{down} = 0.0%
- Objective warning scheme verified well with NHC warnings

	MCP	NHC
Average Distance Warned per TC (mi)	378.6	381.5
Average Warning Duration per TC (hr)	33.6	32.4
	MCP Objective vs. NHC	
MAE, Distance (mi) / Duration (hr)	65 / 5	
R^2, Distance	0.94 / 0.74	

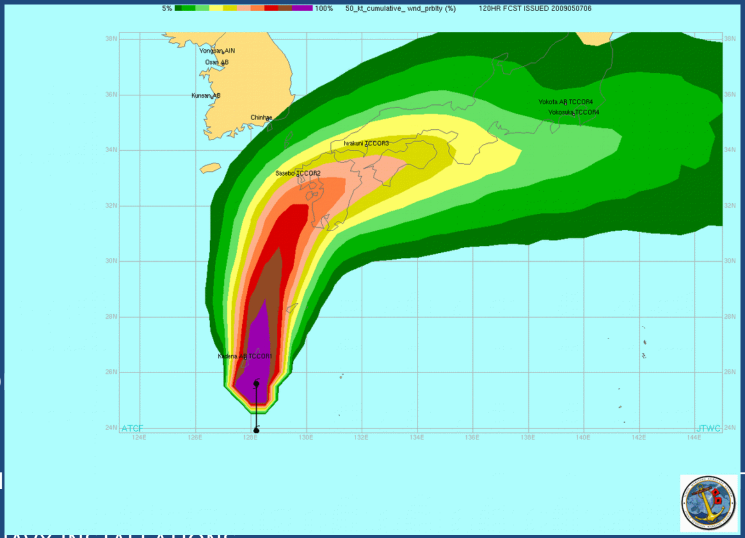
E.g. NHC (top) and objective scheme (bottom) warnings for Hurricane Gustav, 2008.

- Used similar methodology to develop similar schemes for TC-COR (64-kt winds at t=24, 36, 60, and 84 h)

EXPERIMENTAL TC-COR SETTINGS

SITE	TC-COR
Atsugi	4
Camp Fuji	3
Camp Zama	4
Iwakuni	3
Kadena AB	1
Narita Airport	4
Pusan	3
Sasebo	2
Tokyo	4
Yokosuka	4
Yokota AB	4
Yokohama	4

*** BASED ON JTWC WARNING NR 020 FOR TYPHOON 88W (CO



NOTES:

TC-COR SETTINGS ARE BASED ON RELATIONSHIP BETWEEN HURRI TIES IN TH ATLANTIC AND GULF OF MEXICO.

THEY ARE OBJECTIVE GUIDANCE FOR ONSET OF 50 KT WINDS AT NAVY INSTALLATIONS.

EACH SITE HAS ITS OWN SENSITIVITIES, WHICH THESE TC-COR SETTINGS DO NOT ADDRESS.

THE FOLLOWING CUMULATIVE PROBABILITIES ARE USED FOR THE TC-CORR THRESHOLDS:

TC-COR4 5% PROBABILITY OF 50 KT AT 72 H

TC-COR3 6% PROBABILITY OF 50 KT AT 48 H

TC-COR2 8% PROBABILITY OF 50 KT AT 24 H

TC-COR1 12% PROBABILITY OF 50 KT AT 12 H

END OF EXPERIMENTAL TC-COR SETTINGS

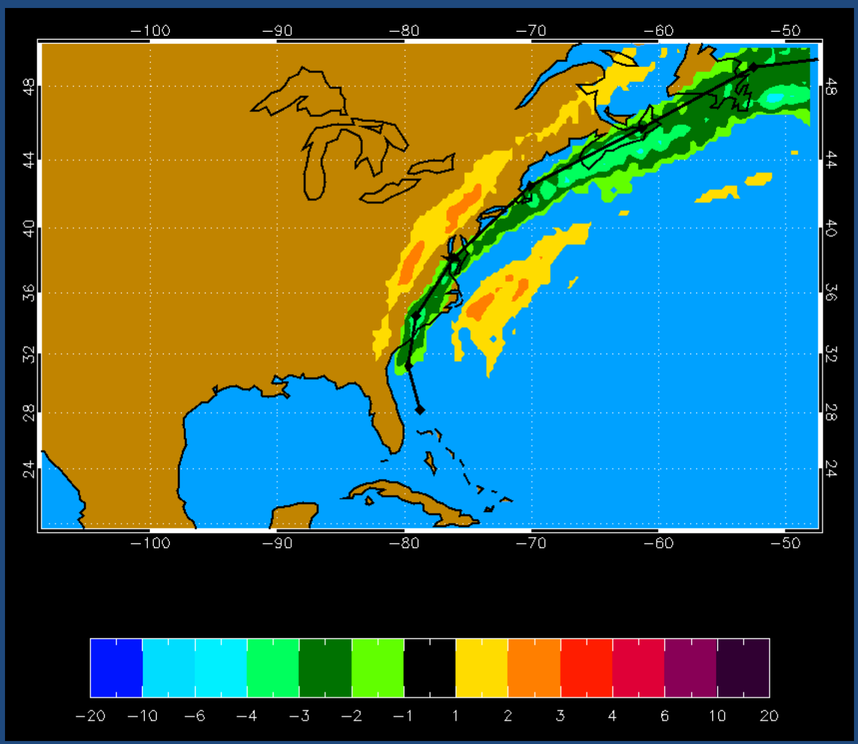
TC-COR2 Threshold same as for NHC Hurricane Warning

MC Model Improvement:

- Operational model uses same error distributions for all forecasts
- Experimental version under development
  - Use GPCE input as a measure of track uncertainty
    - GPCE ≡ Goerss Predicted Consensus Error
  - Divide track errors into three groups based on GPCE values
    - Low, Medium and High
  - Different forecast times can use different distributions
  - Tested on 2008 Atlantic cases near land

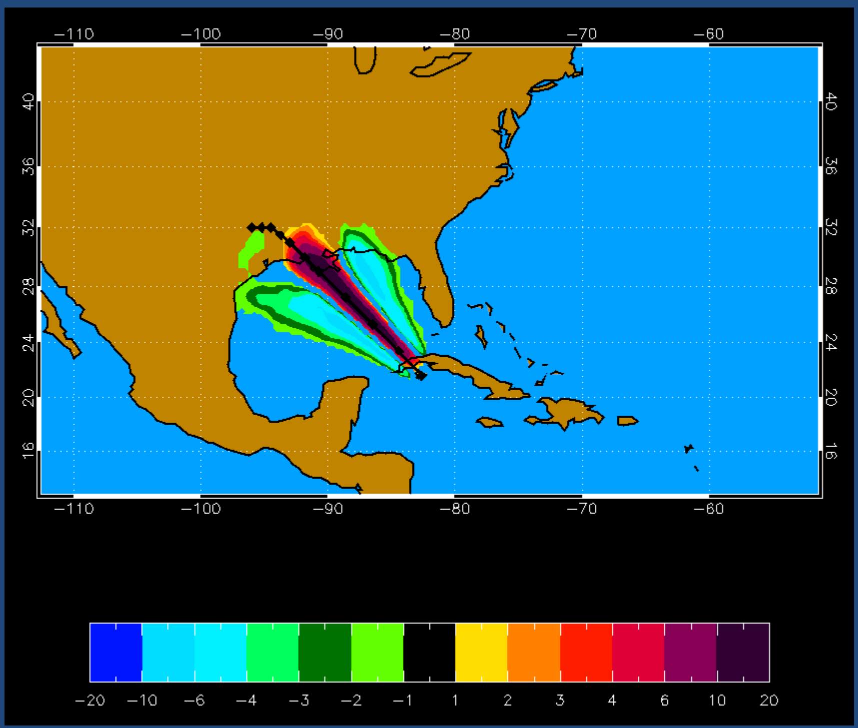
34-kt, 120-h Cumulative Probabilities Current – GPCE Differences

“High Uncertainty Group”



Tropical Storm Hanna 5 Sept 2008 12 UTC

“Low Uncertainty Group”



Hurricane Gustav 30 Aug 2008 18 UTC

Future Plans for MC Model

- Test GPCE version in all basins in 2009
  - Results on password protected web page
- Operational transition of GPCE version in 2010 if recommended by NHC
- Automated coastal watch/warnings (JHT project)
- Provide landfall intensity and timing distributions (JHT project)

Intensity Forecasting Using the Logistic Growth Equation

- SHIPS and STIPS
  - Predict intensity changes using linear regression
  - Some skill relative to climatology and persistence models
- Linear regression limitations
  - Intensity change linear function of time-averaged predictors
    - e.g., 48 hr intensity change $\propto$ 48 hr average shear
  - Land effects included in post-processing step
    - Difficulty with water/land/water tracks
  - No constraints on intensity changes
    - Requires large developmental samples
  - Designed to predict the mean (not rapid) changes

Logistic Growth Equation (LGE) Model

$$dV/dt = \kappa V - \beta(V/V_{mpi})^n V$$

(A) (B)

Term A: Growth term, related to shear, structure, e
Term B: Upper limit on growth as storm approache
its maximum potential intensity (V_{mpi})

LGEM Parameters:

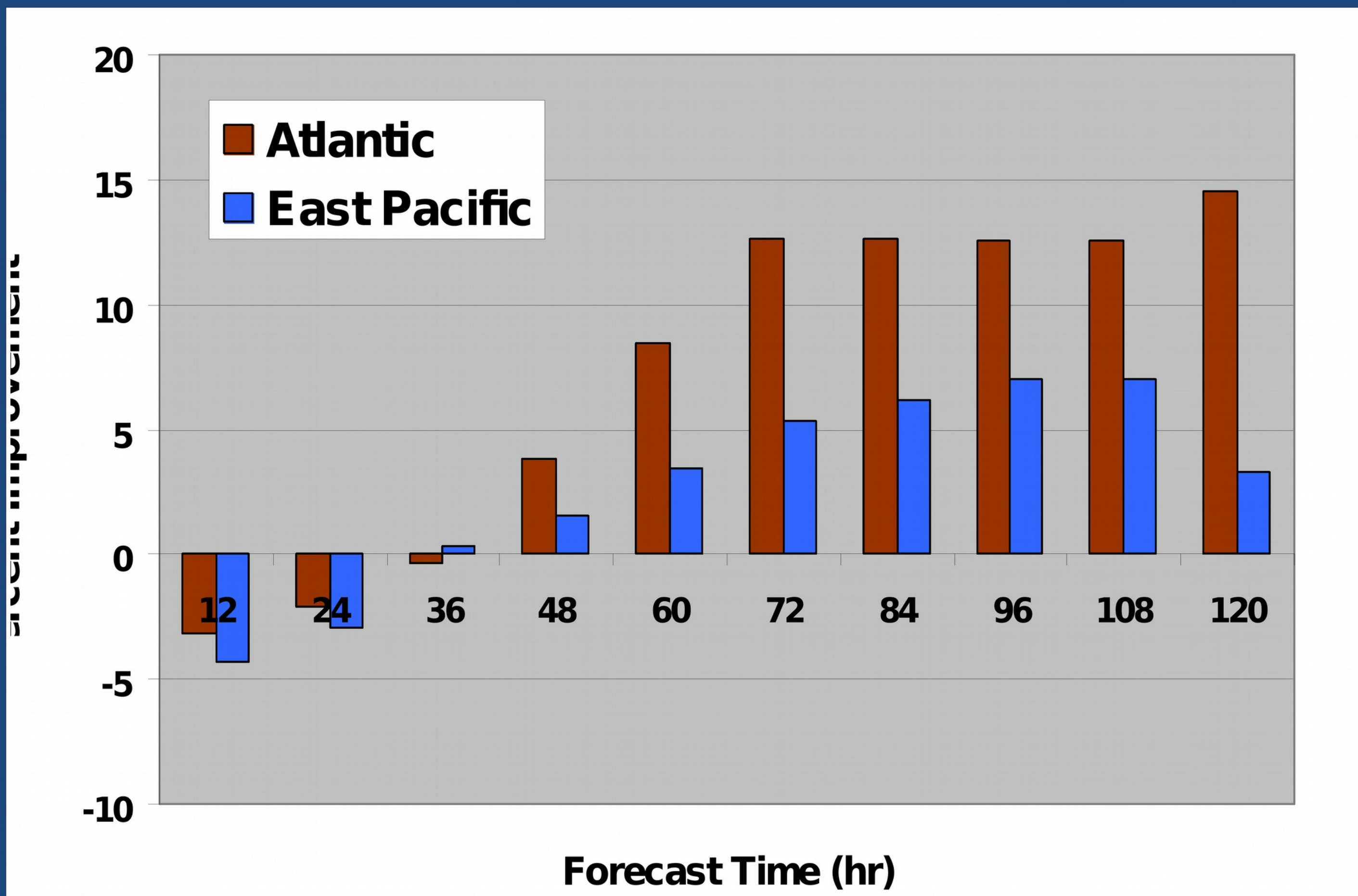
- $\kappa(t)$ Growth rate F(shear, RH, intensity, etc
- β MPI relaxation rate
- $V_{mpi}(t)$ MPI ≡ Maximum Potential Intensity F(
- n "Steepness" parameter

Growth rate replaced by Kaplan and DeMaria inland
Decay rate over land

LGE vs SHIPS/STIPS

- Advantages
  - Intensity tendency proportional to instantaneous predictors (shear, etc)
  - Land effects included directly
  - Solution constrained between zero and MPI
  - Much smaller number of free parameters
  - Model specific initialization using Adjoint equation
    - Under development
- Disadvantages
  - Persistence harder to include in nonlinear prediction
  - Potential for low bias for weak storms with dV/dt ~ V

LGEM vs SHIPS
2006-2008 Operational Forecasts



Future Plans for LGEM

- Improve model initialization
- Develop west Pacific version**
- Use the WPAC version in the intensity consensus forecasts**
- Generalize MPI to include ocean feedback**
- Modify growth rate based on balance model theory**

**Timing depends on success of NOPP proposal

References

Bessho, K., M. DeMaria, and J.A. Knaff , 2006: Tropical Cyclone Wind Retrievals from the Advanced Microwave Sounder Unit (AMSU): Application to Surface Wind Analysis. *J. of Applied Meteorology.* 45:3, 399-415.

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Mueller, K.J., M. DeMaria, J.A. Knaff, J.P. Kossin, T.H. Vonder Haar:, 2006: Objective Estimation of Tropical Cyclone Wind Structure from Infrared Satellite Data. *Wea Forecasting,* 21:6, 990–1005.

Schumacher, A.B., M. DeMaria and J.A. Knaff, 2009: Objective Estimation of the 24-Hour Probability of Tropical Cyclone Formation, *Wea. Forecasting*, 24, 456-471.

Published papers are available at http://rammb.cira.colostate.edu/resources/publications.asp

Back up slides

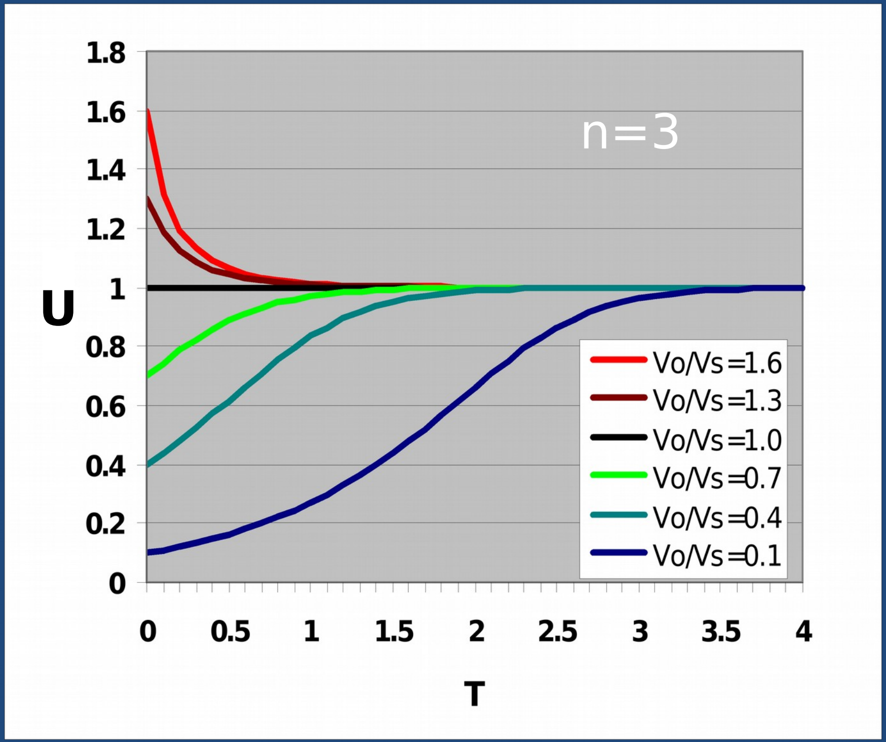
Analytic LGE Solutions for Constant β, κ, n, V_{mpi}

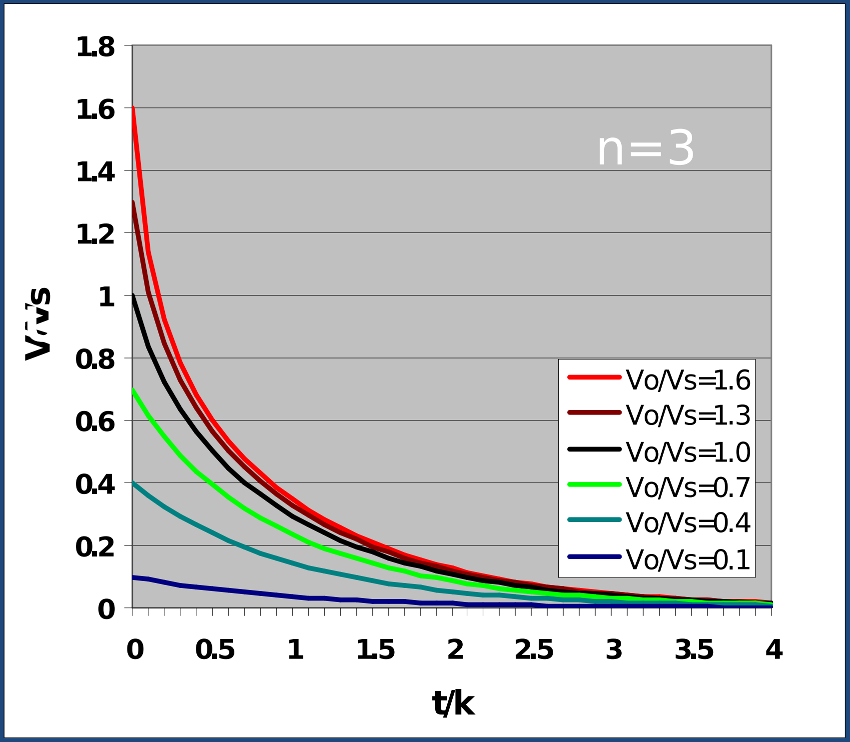
V_s = Steady State V = $V_{mpi}(\kappa/\beta)^{1/n}$

Let $U = V/V_s$ and $T = \kappa t$

$dU/dT = U(1-U^n)$

$U(t) = U_o\{e^{nT}/[1 + (e^{nT}-1)(U_o)^n]\}^{1/n}$

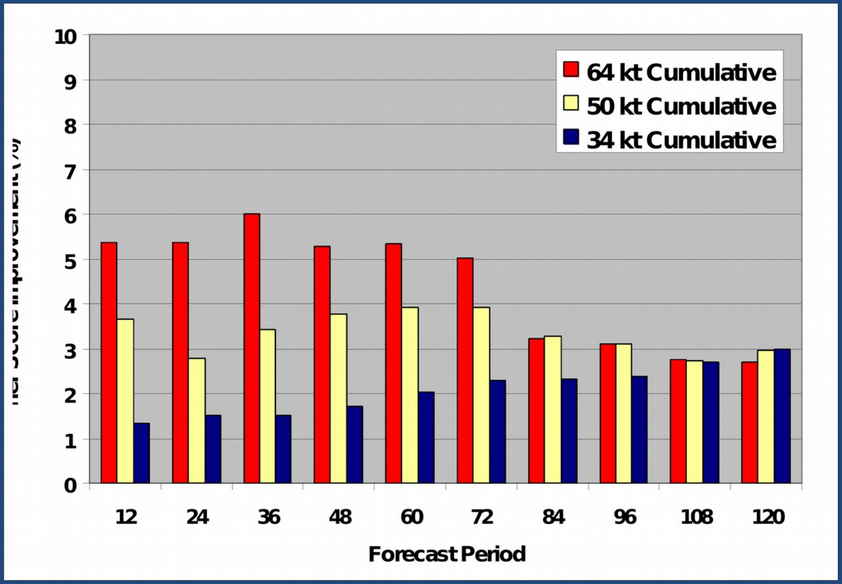




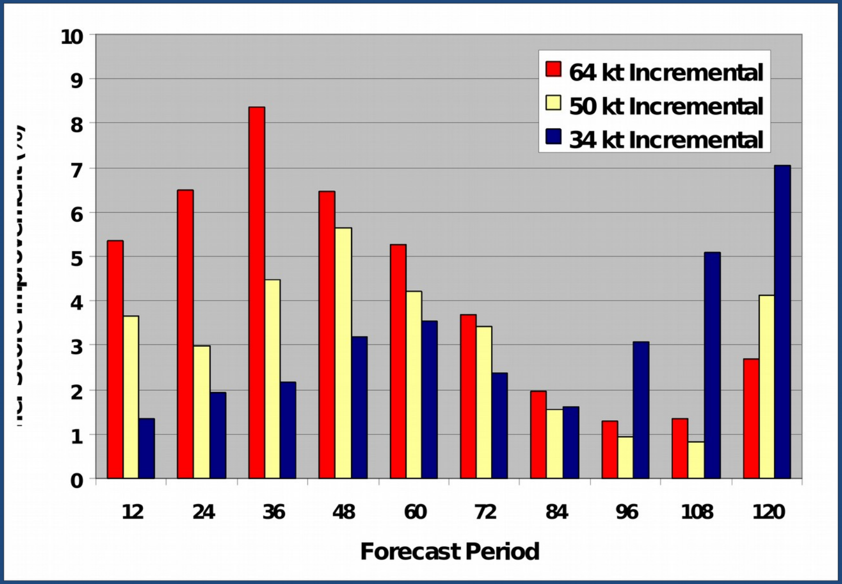
κ > 0

κ < 0

Brier Score Improvements 2008 GPCE MC Model Test for the Atlantic

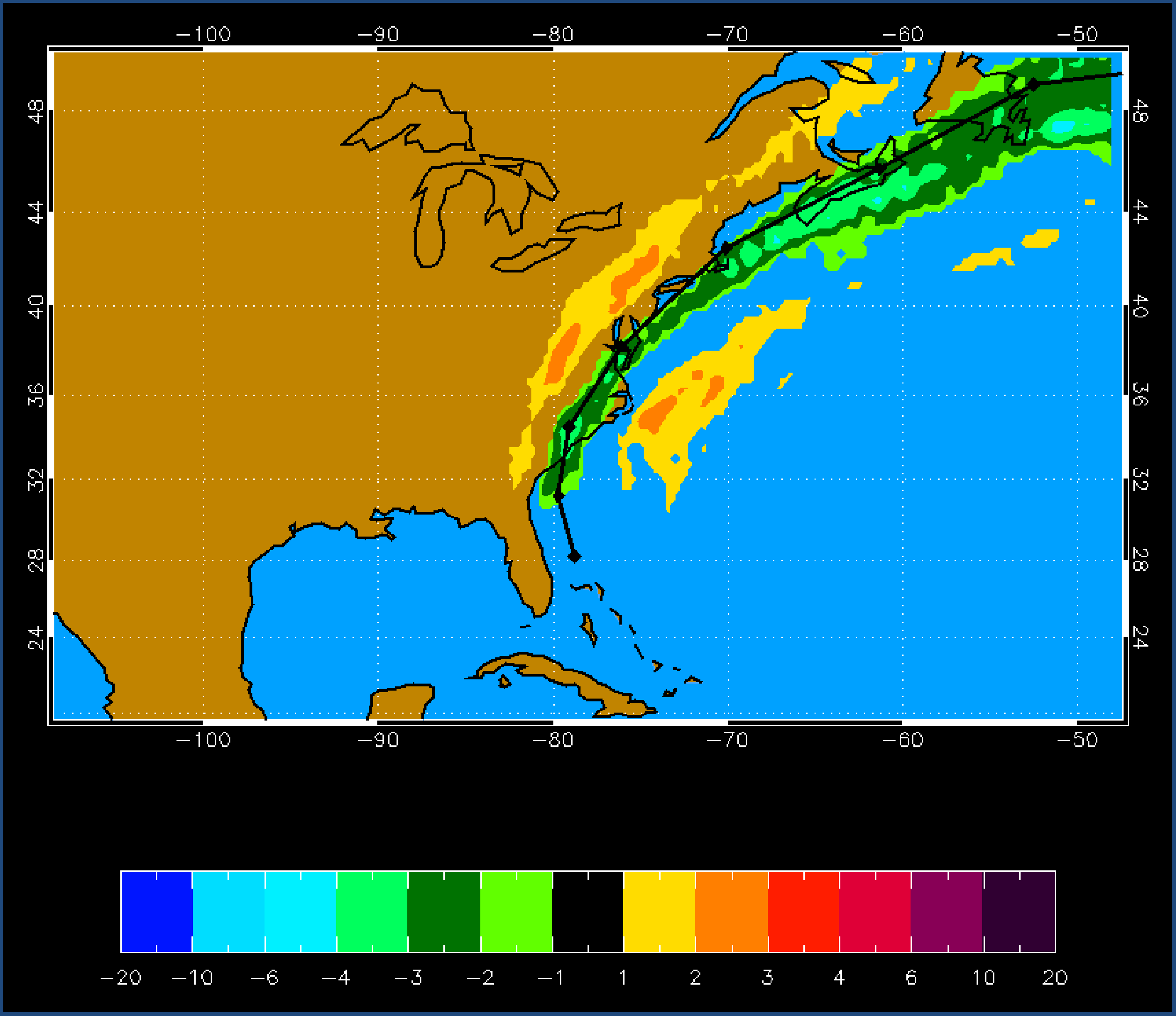


Cumulative



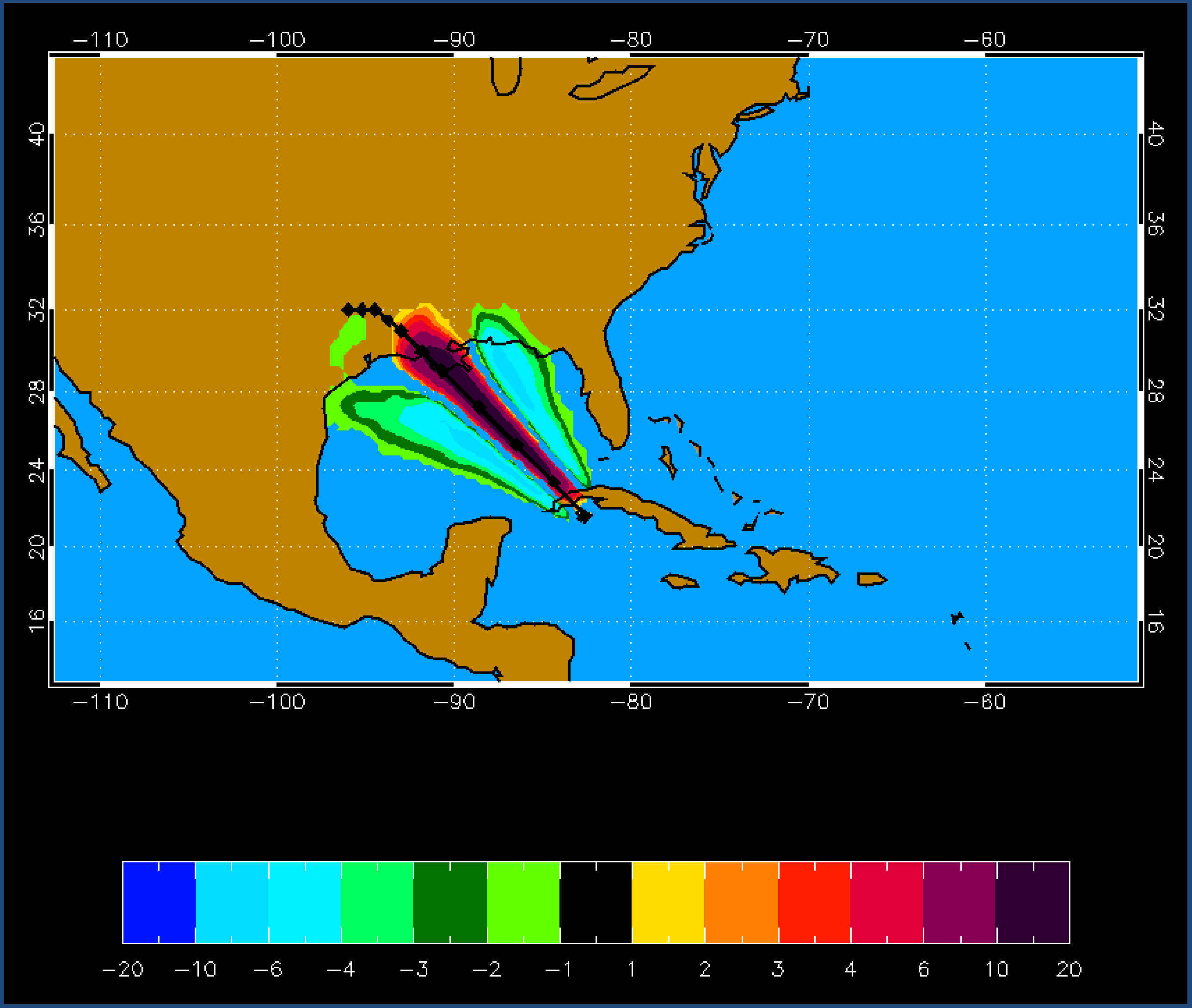
Incremental

Tropical Storm Hanna 5 Sept 2008 12 UTC



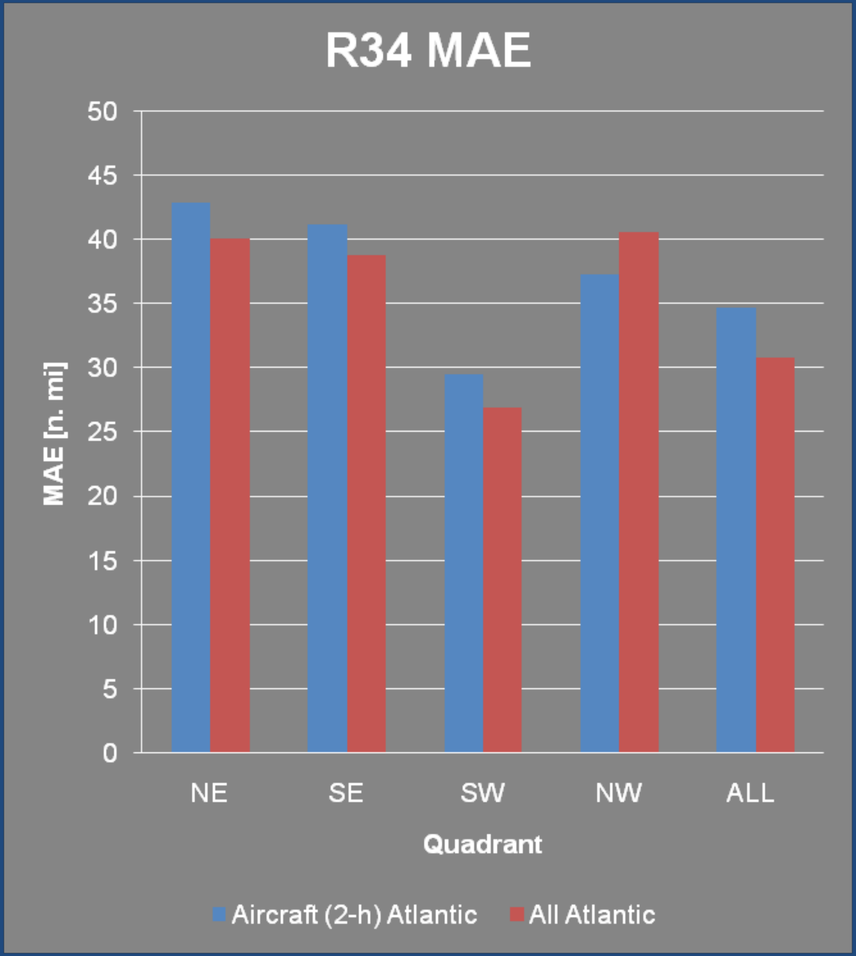
34 kt 0-120 h cumulative probability difference field (GPCE-Operational)

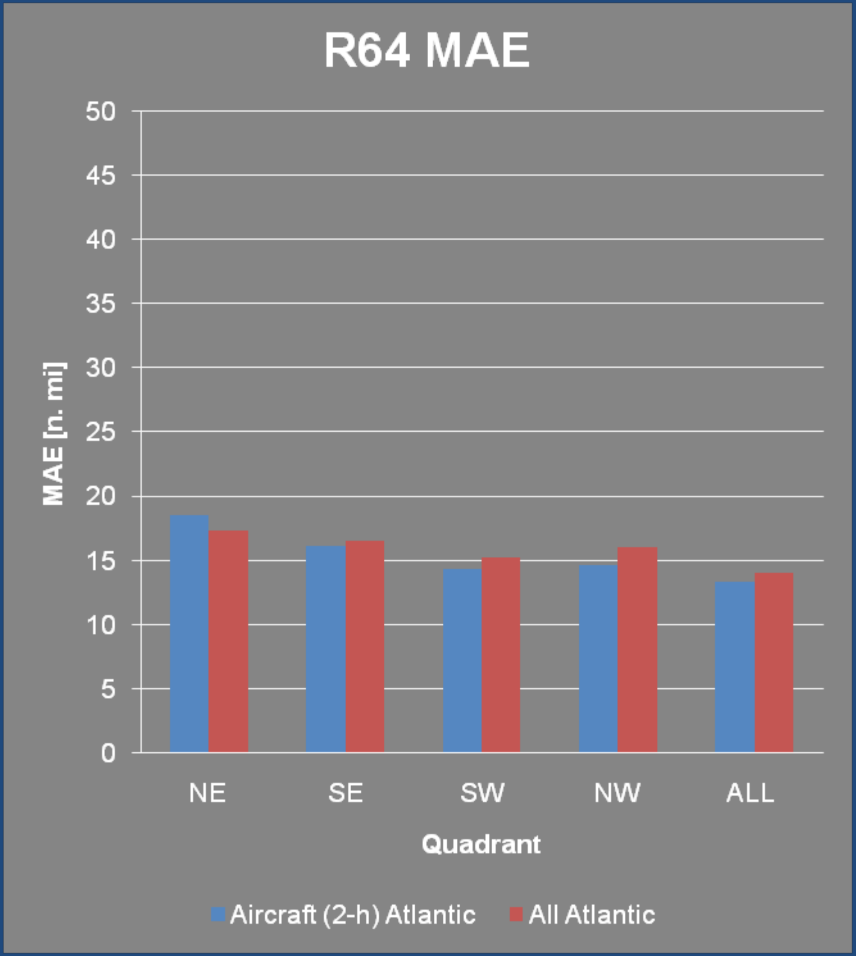
Hurricane Gustav 30 Aug 2008 18 UTC



64 kt 0-120 h cumulative probability difference field (GPCE-Operational)

2008 Atlantic Verification with Recon





Full verification available from John.Knaff@noaa.gov